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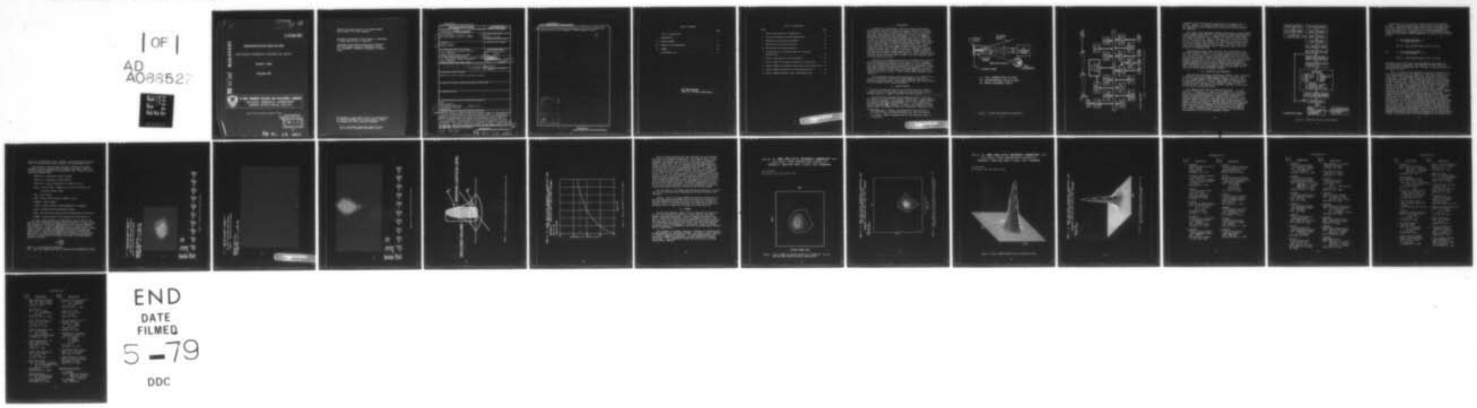

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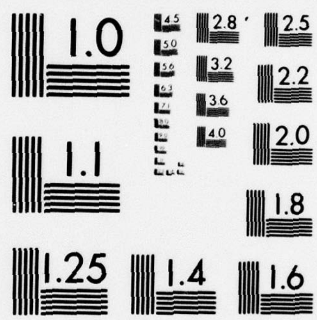
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MEMORANDUM REPORT ARBRL-MR-02882

BRL BEAM DIAGNOSTIC SUPPORT OF UNFTP

Morgan T. Reedy

November 1978

US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
BALLISTIC RESEARCH LABORATORY
ABERDEEN PROVING GROUND, MARYLAND

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Infrared Data Processing
Beam Quality

cont'd p. 1

(UNFTP)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This ~~The~~ report presents a summary of BRL Beam Diagnostic Support of the Unified Navy Field Test Program recently concluded at Capistrano Beach, CA. ~~The report~~ It discusses the role of the BRL Infrared Data Acquisition and Processing System, IRDAPS in providing quick look analytical beam diagnostic data as inputs to on-site management decisions regarding beam quality and its impact on overall experimental goals. Beam Parameters, as calculated by IRDAPS, are discussed and interpreted. Included are typical data tabulations and plots to support these discussions. This report also points out that, although IRDAPS bore the full

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burden of all on-site beam data processing, at no time was a program delay encountered due to lack of response or IRDAPS equipment failure.

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I. INTRODUCTION

From March 1977 through April 1978 by invitation from the Navy Program Office (PMS-405) the Ballistic Research Laboratory's Infrared Data Acquisition and Processing System (IRDAPS) served as the on-site, quick-look, beam diagnostic data processing system for the Aimpoint Maintenance Unified Navy Field Test Program. In this role IRDAPS was utilized for recording and processing beam quality data at the 500 m receiver site and for processing quick-look beam diagnostic data from each of four additional IR camera locations along the beam path up beam of the entrance aperature to the Navy Pointer/Tracker (NPT). The four camera locations, were at the upper cylindrical mirror, the lower cylindrical mirror, the TRW diagnostic bench and downbeam of the Beam Expander Telescope (BXT). Figure 1 illustrates a typical scatterplate technique used to generate beam diagnostic data. Cameras consisted of both EG&G and AGA types; the EG&G (125 frames, 30 lines) provided moderate frequency resolution and the AGA (16 frames, 100 lines) provided reasonable high spatial resolution.

Objectives of the IRDAPS participation in the UNFTP were to provide quick analytical beam diagnostic data as inputs to on-site management decisions regarding beam quality and its impact on overall experimental goals and to provide high quality graphical data as supplements to quick-look reports submitted periodically to program management. To be fully effective a majority of these analytical results were required within minutes after the test firing. To this end the IRDAPS performed exceedingly well.

In the following sections a brief description of the IRDAPS[1,2] will be given, followed by a discussion of data parameters (how they were obtained and what they mean). Data samples from both EG&G and AGA cameras will be included to aid in these discussions.

II. IRDAPS OVERVIEW

The BRL Infrared Data Acquisition and Processing System (IRDAPS) is a computer based, field portable, acquisition and processing facility designed expressly to support remote HEL field test programs. → (cont on p 1423A)

As seen from the functional block diagram of Figure 2 a PDP-11/15 minicomputer is the heart of the system. The PDP-11/15 is amply supported by a host of peripherals - Disk Operating System (DOS), Graphics Display I/O Terminal, High Speed Printer/Plotter, etc. - all of which tend to make the system extremly versatile. To add to this versatility the DOS operates under the auspices of DEC RT-11 software and, therefore, can be

1. M.T. Reedy and E.P. Weaver, "An Infrared Data Acquisition and Processing System", BRL Memorandum Report No. 2790. (AD #A051182)
2. E.P. Weaver, "IRDAPS Programming Manual", BRL Memorandum Report to be published.

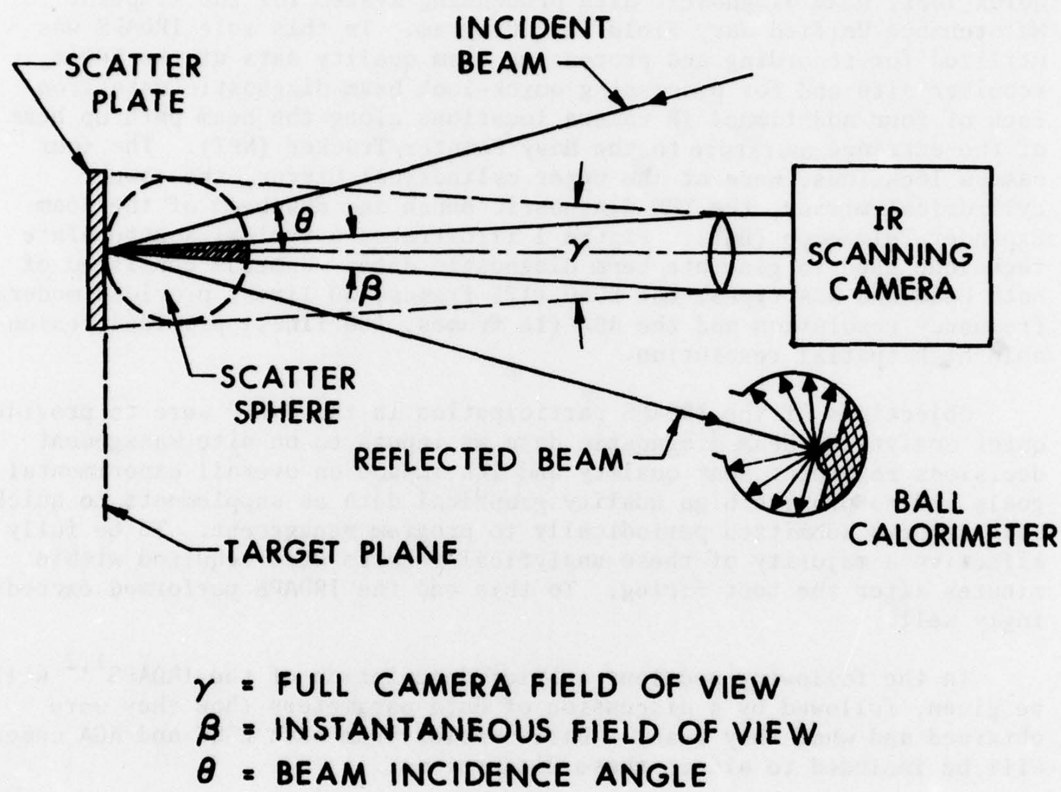

Figure 1: Typical Beam Diagnostic Configuration

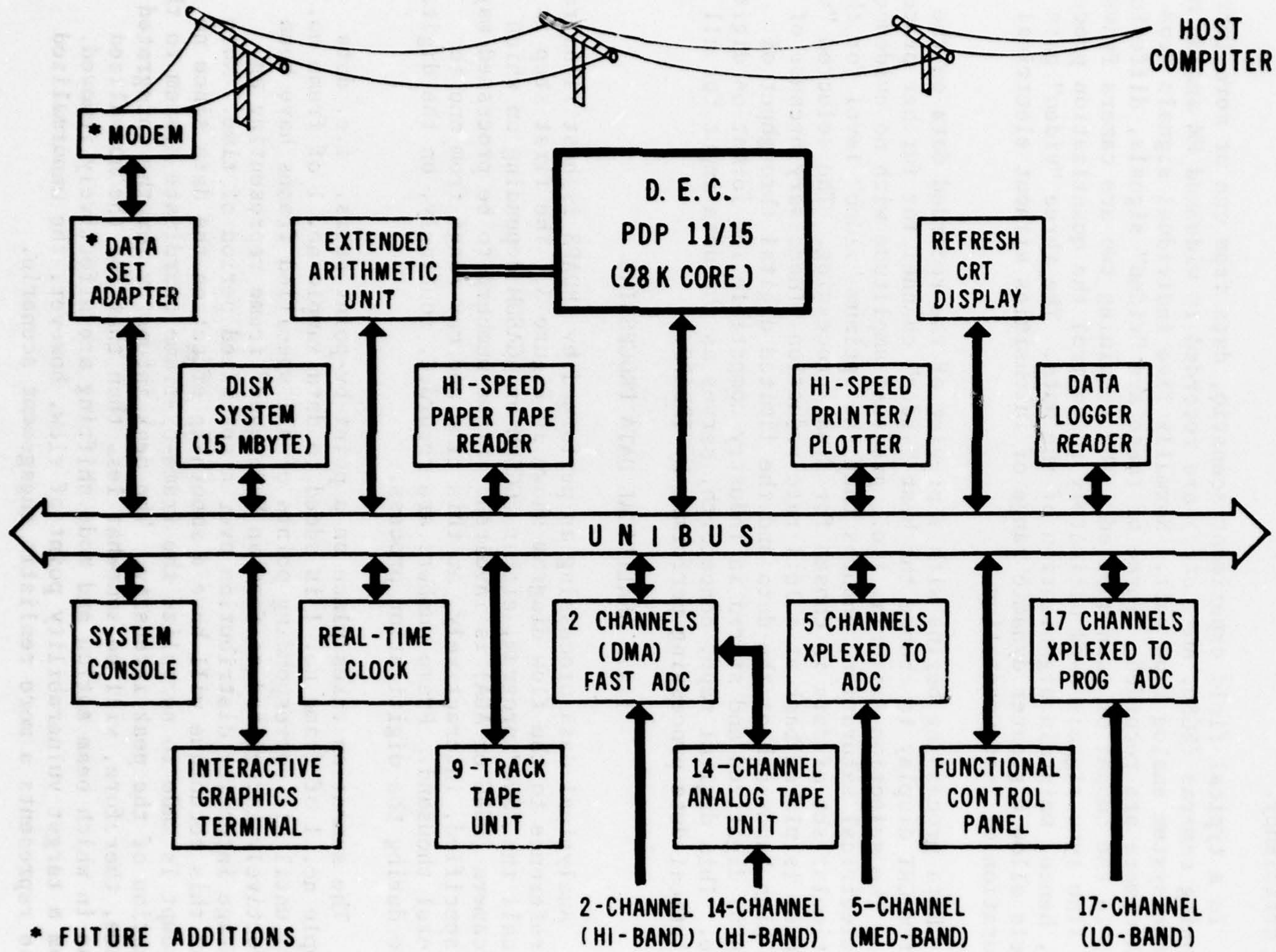

Figure 2: Functional Diagram of the BRL IRDAP System

programmed quickly and efficiently using high level languages such as Fortran. Moreover, the Graphics Terminal and the Printer/Plotter are well supported by Fortran callable plot routines which enhance data output efficiency.

In a typical field experiment scenario, data from one or more infrared scanning cameras (EG&G, AGA, etc.) are recorded in wideband FM analog mode on the system analog tape unit. Normally five individual signals from each camera are recorded. Three of these are "video" signals, differing only in the amount of gain applied. The remaining two are camera frame and line sync signals used ultimately to control the quantization process and, hence, maintain organization of the data. The three "video" gain levels allow a greater dynamic range of intensities without electrical saturation of instrumentation.

Data processing begins with a preview of the recorded data on the system CRT display to choose the best "video" channel for further processing. The selection criteria, i.e., greatest amplitude with no evidence of electrical saturation, ensures that the optimum "video" level for that particular set of data is chosen for final processing. The selected "video" channel is played back at a 16:1 rate reduction, (necessary because of the high bandwidth of the data and the limited digital throughput of IRDAPS) digitized and stored in industry compatible IBM format on digital tape. This digital tape, henceforth, serves as the data input for all analytical data processing performed by IRDAPS.

III. ANALYTICAL DATA PROCESSING

Analytical data processing as performed by IRDAPS is best illustrated by reference to the flow diagram shown in Figure 3. The first step is to call the "SUM" program, either EGGSUM or AGASUM depending on which IR camera (EG&G or AGA) is involved. Frame numbers to be processed may be specified, interactively, at this time and may range from one to several thousand. Frame numbers are recorded, routinely, on the digital tape during the digitization process.

The summation takes place on a point-by-point basis. i.e. data sample no. 1 of frame no. 1 is added to data sample no. 1 of frame no. 2, etc, until all corresponding points of all specified frames have been effectively integrated to form an "averaged" frame representing an average intensity distribution over a specified period of time. Note that this technique will have a smoothing effect on the data since no attempt is made to normalize the frame-by-frame coordinate system to the location of the peak intensity. The peak intensity for the integrated frame, therefore, will be somewhat less than that for the normalized case in which beam motion and mode shifting are effectively removed. From a target vulnerability point of view, however, the unnormalized case represents a more realistic engagement scenario.

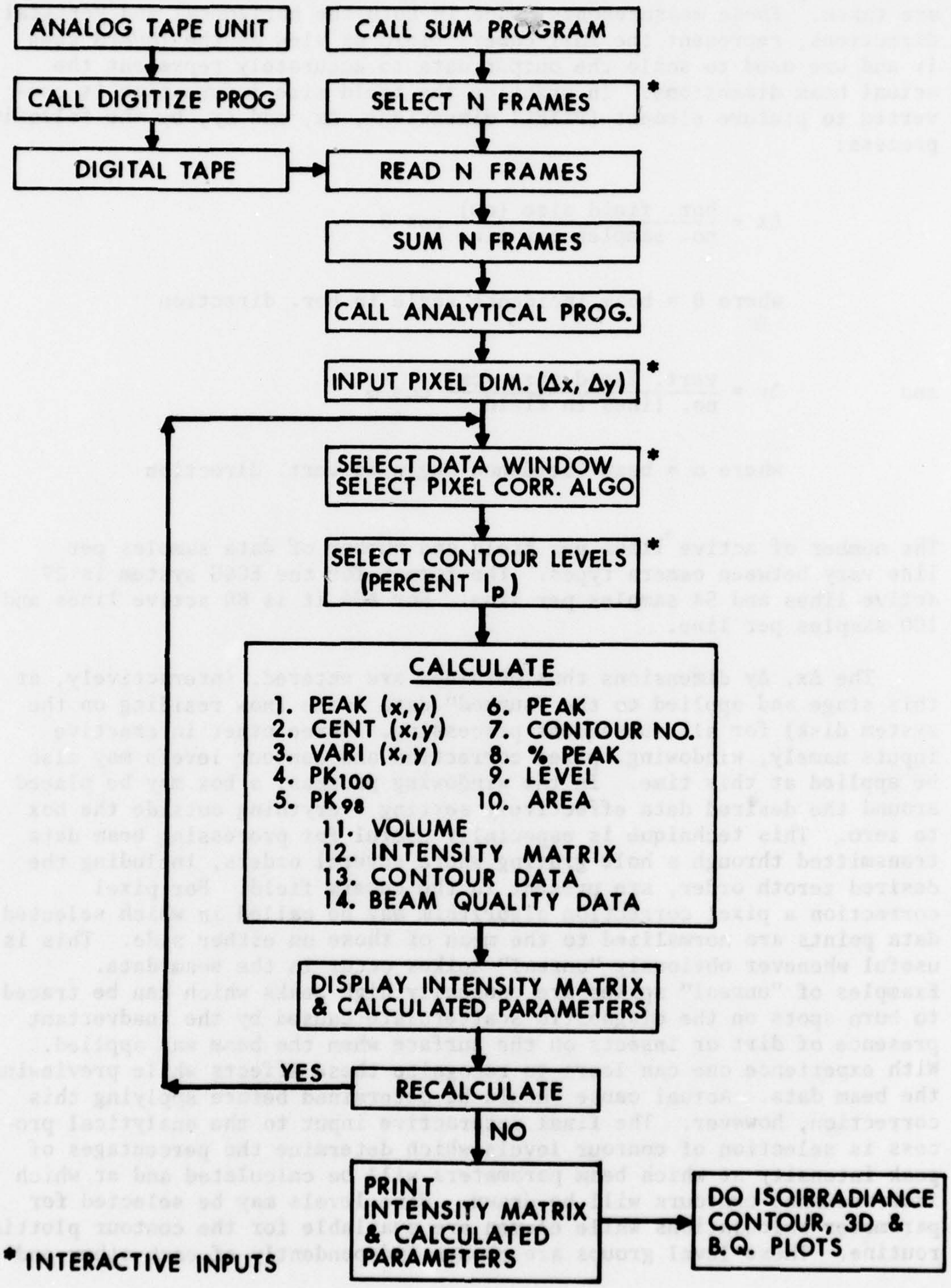

Figure 3: IRDAPS Data Processing Flow Diagram

During setup of the IR cameras, accurate field size measurements are taken. These measurements, made in both the horizontal and vertical directions, represent the full camera field of view as the IRDAPS sees it and are used to scale the output data to accurately represent the actual beam dimensions. In practice the field size information is converted to picture element (PIXEL) dimensions, Δx, and Δy, by the following process:

$$\Delta x = \frac{\text{hor. field size (cm)}}{\text{no. samples per line}} \cos \theta$$

where θ = beam incidence angle in hor. direction

and

$$\Delta y = \frac{\text{vert. field size (cm)}}{\text{no. lines in field}} \cos \alpha$$

where α = beam incidence angle in vert. direction

The number of active lines per field and number of data samples per line vary between camera types. The format for the EG&G system is 27 active lines and 54 samples per line. For AGA it is 80 active lines and 100 samples per line.

The Δx, Δy dimensions thus obtained are entered, interactively, at this stage and applied to the "summed" data frame (now residing on the system disk) for all subsequent processing. Three other interactive inputs namely, windowing, pixel correction and contour levels may also be applied at this time. In the windowing process, a box may be placed around the desired data effectively setting everything outside the box to zero. This technique is especially useful for processing beam data transmitted through a hole grating where several orders, including the desired zeroth order, are present in the camera field. For pixel correction a pixel correction algorithim may be called in which selected data points are normalized to the mean of those on either side. This is useful whenever obviously "unreal" spikes occur in the beam data. Examples of "unreal" spikes are unusually high peaks which can be traced to burn spots on the diagnostic scatterplate caused by the inadvertant presence of dirt or insects on the surface when the beam was applied. With experience one can learn to recognize these effects while previewing the beam data. Actual cause should be determined before applying this correction, however. The final interactive input to the analytical process is selection of contour levels which determine the percentages of peak intensity at which beam parameters will be calculated and at which isoirradiance contours will be drawn. Nine levels may be selected for parameter calculations while eleven are available for the contour plotting routine. These level groups are chosen independently of each other and

need not be corresponding levels. However, in practice the first several levels in each group are usually selected to be corresponding levels.

The next box in the flow chart contains a listing of calculated parameters routinely computed from the "summed" data frame. These are listed in order of occurrence on the tabulation sheets (Figures 4 and 4a) and briefly defined below:

- PEAK (x,y) - Coordinates of peak intensity
- CENT (x,y) - Coordinates of beam centroid
- VARIA (x,y) - Spatial variance (σ^2) of CENT in x and y
- PK_{100} - Ratio of PEAK to VOLUME (C_2), used as scale factor for Peak Power Density (PPD)
- PK_{98} - 98% of PK_{100}
- PEAK - Relative peak intensity, computer counts
- CONTOUR - Contour number
- % PEAK - Percent of PEAK at which parameters are computed
- LEVEL - Relative level of individual contours
- AREA - Area (cm^2) of the beam cross section defined by the contour
- VOLUME - Included volume at that contour level (See Figure 5).

The above listed parameters are identified by name on the data tabulation sheets containing the relative intensity matrices (Figures 4 & 4a). Data necessary to generate the "Beam Quality" plots are also contained in these tabulations. A typical "Beam Quality" Plot is shown in Figure 6. Plotted along the ordinate is Normalized Volume or Relative Power. Plotted along the abcissa is Beam Cross Sectional Area (cm^2) at the specified contour levels. The horizontal dashed line represents the 63 percent power point. The beam cross sectional area at the point of intersection with the 63 percent power line serves as one input to the Beam Quality equation as follows:

$$\beta = \left(\frac{A_M}{A_t}\right)^{\frac{1}{2}}$$

where, A_t is the theoretical beam area
and, A_M is the measured beam area as determined from "Beam Quality" plots.

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   HIGH ENERGY LASER PROGRAM BEAM DIAGNOSTICS

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COMMENTS: 64 FR.AVG.,18-81,DX=.222,DY=.505
NACL RUN VL2-305                  CODE  1101
  64 FRAMES FROM     18 ON, TIME 23 40 42.042

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COORD	X	Y
PEAK	4.995	5.302
CENT	5.519	5.784
VARIA	0.044	0.020
PK100	0.245	
PK98	0.240	
PEAK	6927.000	

CONTUR	0	1	2	3	4	5	6	7	8	9
% PEAK	0.0	1.0	10.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0
LEVEL	0.000	69.270	692.700	2078.100	2770.800	3463.500	4156.200	4848.900	5541.600	6234.300
AREA	163.456	23.655	10.090	4.821	3.251	2.354	1.570	1.345	0.785	0.561
% FLUX	100.0	93.2	81.2	60.9	49.1	40.0	29.6	26.3	16.6	12.3

Figure 4. EG&G Data Tab and Intensity Matrix

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HIGH ENERGY LASER PROGRAM BEAM DIAGNOSTICS

PROJECT: UNIFIED NAVY FIELD TEST PROGRAM

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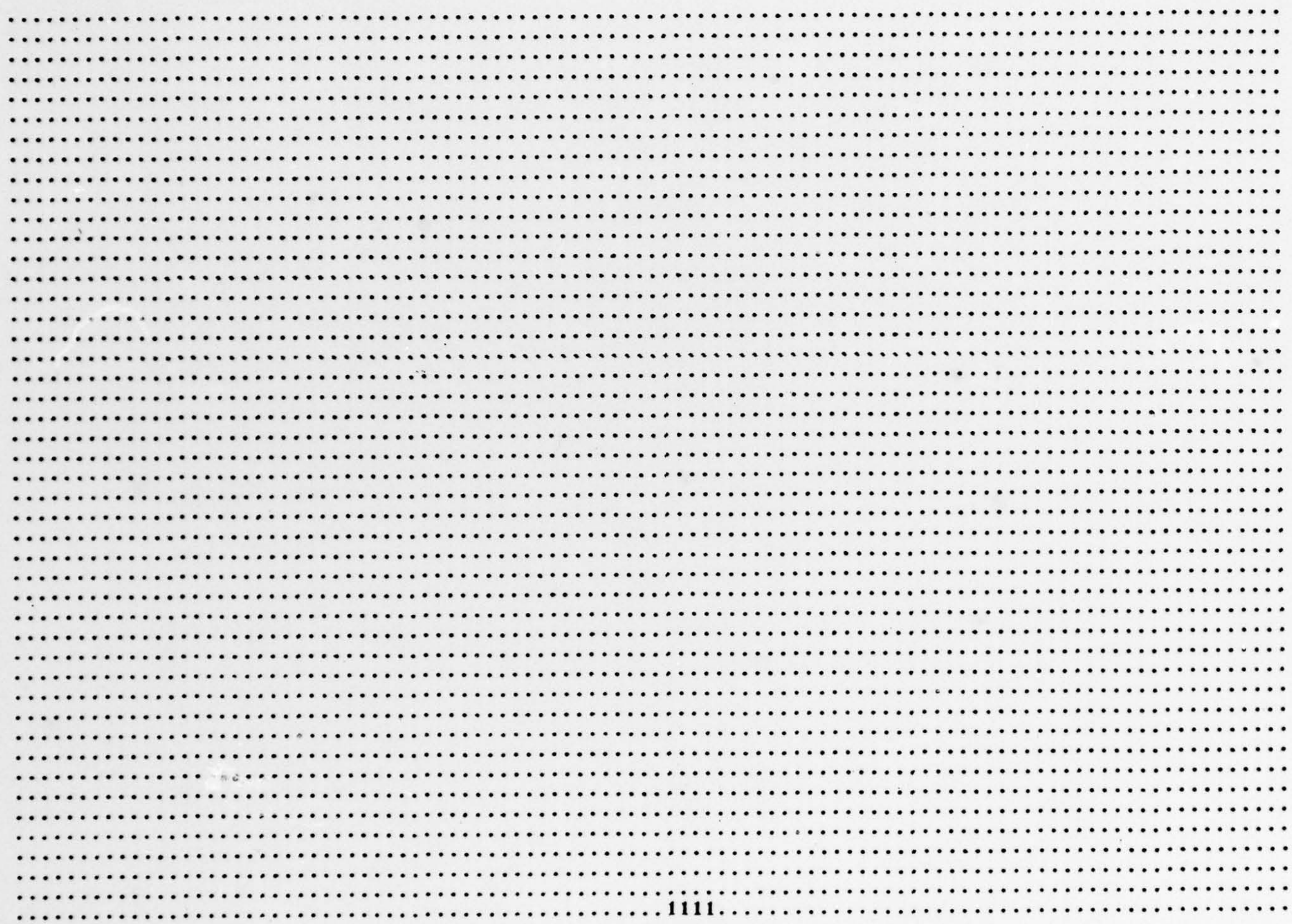

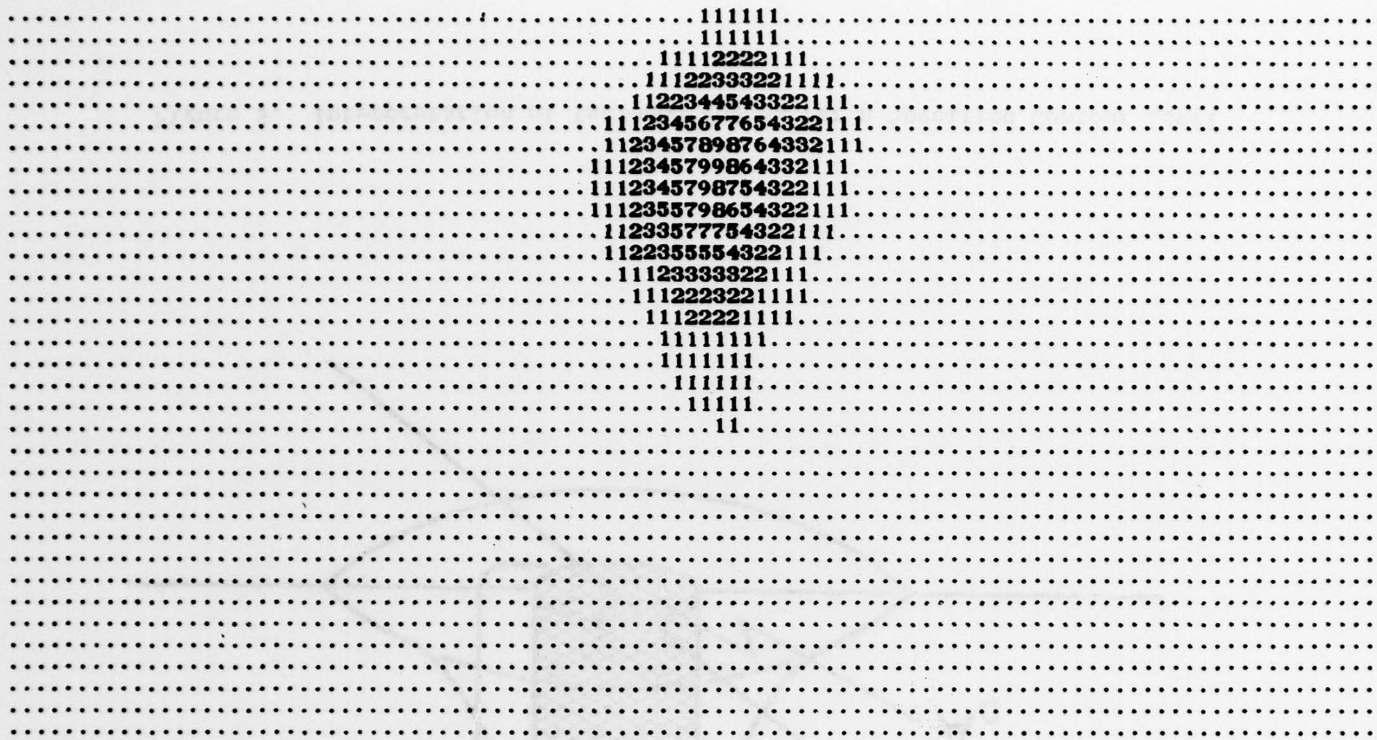

COORD	X	Y
PEAK	7.575	4.452
CENT	7.723	4.263
VARIA	0.012	0.093
PK100	0.538	
PK98	0.528	
PEAK	2026.000	

CONTUR	0	1	2	3	4	5	6	7	8	9
% PEAK	0.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0
LEVEL	0.000	202.600	405.200	607.800	810.400	1013.000	1215.600	1418.200	1620.800	1823.400
AREA	201.600	6.325	3.251	2.142	1.411	1.058	0.655	0.529	0.252	0.126
% FLUX	100.0	67.5	51.9	41.9	32.4	26.6	18.6	15.7	8.3	4.4

Figure 4a. AGA Data Tab and Intensity Matrix

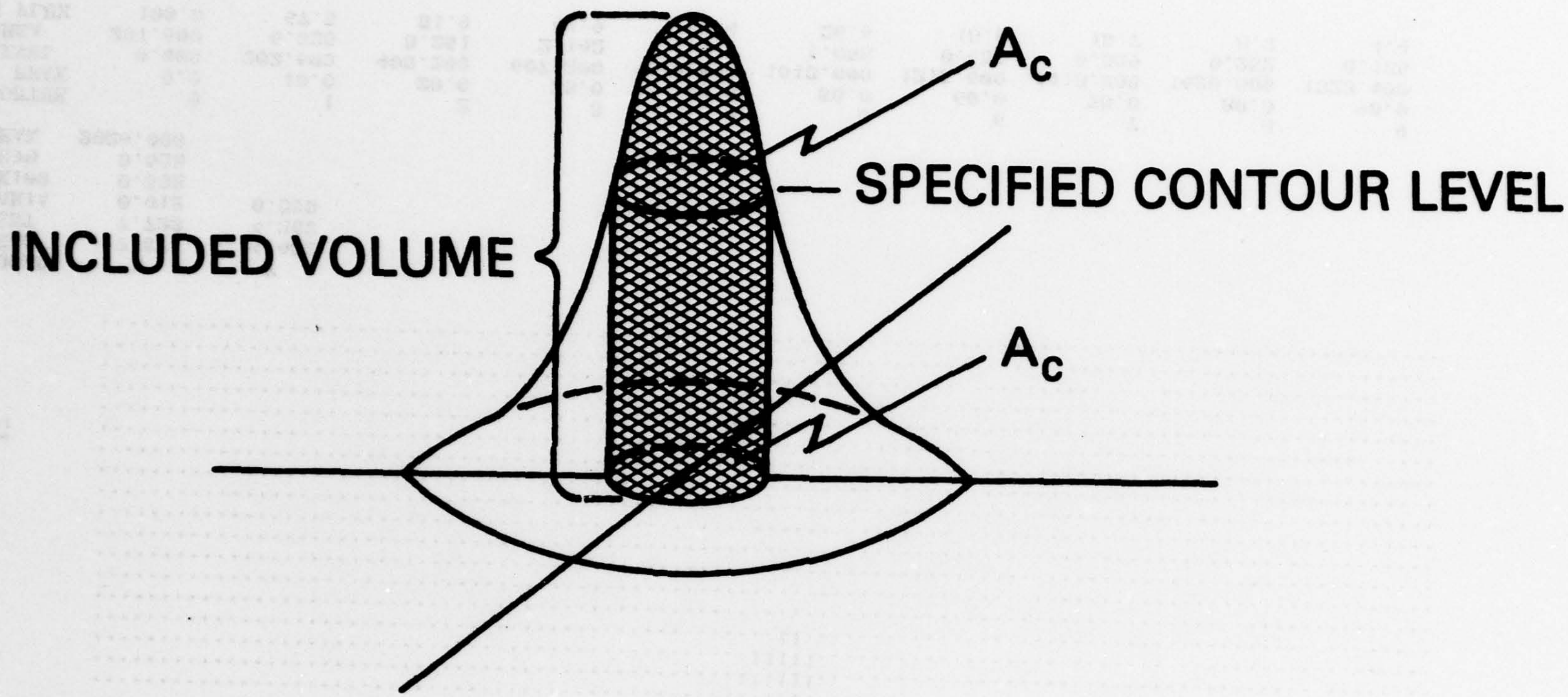

Figure 5. Interpretation of Included Volume for a Specified Contour Level

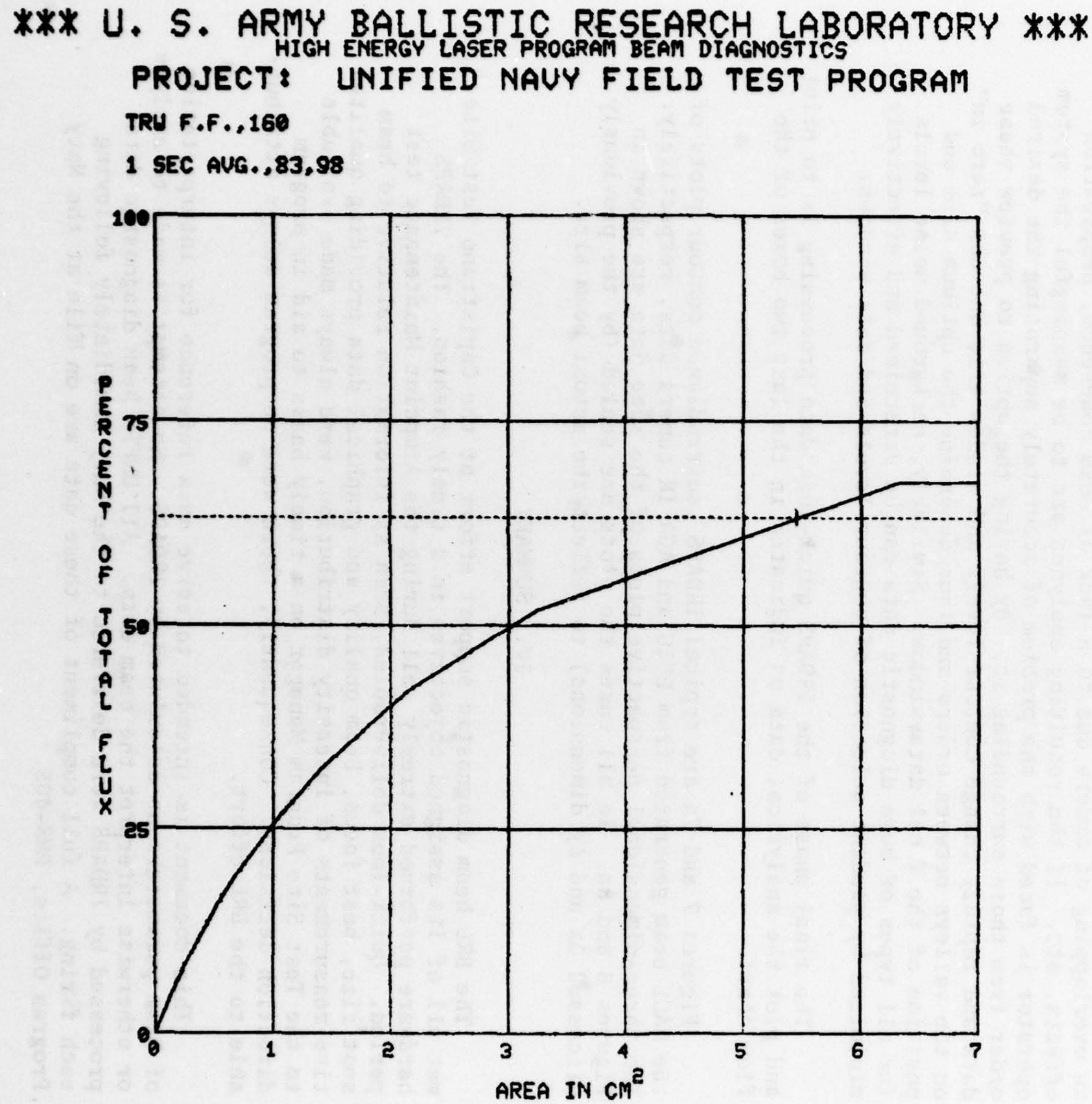

Figure 6. Typical "Beam Quality" Plot from IRDAPS

After all beam parameters have been calculated they are displayed for review on the Graphics Terminal CRT. The intensity matrix is also displayed. The operator has the option at this time to continue and print/plot the presented data as is or go back and change the data window, contour levels, etc. as necessary to exclude undesirable data. Extreme care must be exercised in selecting data windows in order not to preclude data pertinent to experimental analyses. For example, low power beam quality data propagated through a hole grating will exhibit an overlapping of orders due to a lack of beam coherence, propagation effects, etc. If the resulting analyses are to be meaningful the system operator is faced with the problem of accurately separating the desired order from those surrounding it. By having the option to preview these data and rapidly change contour levels and window size one can "zero in" on the valleys between orders and thus determine the optimum size and position of the final data window. Similarly, background noise levels for all types of beam diagnostic data can be determined and effectively minimized by prudent selection of contour levels and data windows.

The final phase of the IRDAPS quick-look data processing is to print and plot the analytical data as indicated in the last two boxes of the flow chart.

Figures 7 and 7a are typical IRDAPS isoirradiance contour plots of the NACL beam generated from EG&G and AGA IR camera data, respectively. The three-dimensional perspective plots of the same data are shown in Figures 8 and 8a. In all cases the plots are scaled (by the previously discussed Δx and Δy dimensions) to reflect the actual beam size.

IV. SUMMARY

The BRL beam diagnostic support effort at the Capistrano Test Site met all of its assigned objectives in a timely fashion. The IRDAPS hardware performed extremly well during the Aimpoint Maintenance test period. Quick-look deliverables, such as information relative to beam spot size, best focus, beam quality and graphical data providing qualitative measurements of intensity distribution, were always made available to the Test Site Program Manager on a timely basis to aid in program direction decisions. Consequently, there were no program delays attributable to the BRL effort.

This document is intended to serve as a reference for interpretation of beam parameters as calculated by IRDAPS. No attempt is made to analyze or otherwise interpret the beam data. All UNFTP beam diagnostic data processed by IRDAPS were delivered to the Navy immediately following each firing. A full compliment of these data are on file at the Navy Program Office, PMS-405.

*** U. S. ARMY BALLISTIC RESEARCH LABORATORY ***

HIGH ENERGY LASER PROGRAM BEAM DIAGNOSTICS

PROJECT: UNIFIED NAVY FIELD TEST PROGRAM

305 AFTS/POF

64 FR.AVG.,18-81,DX=.222,DY=.505

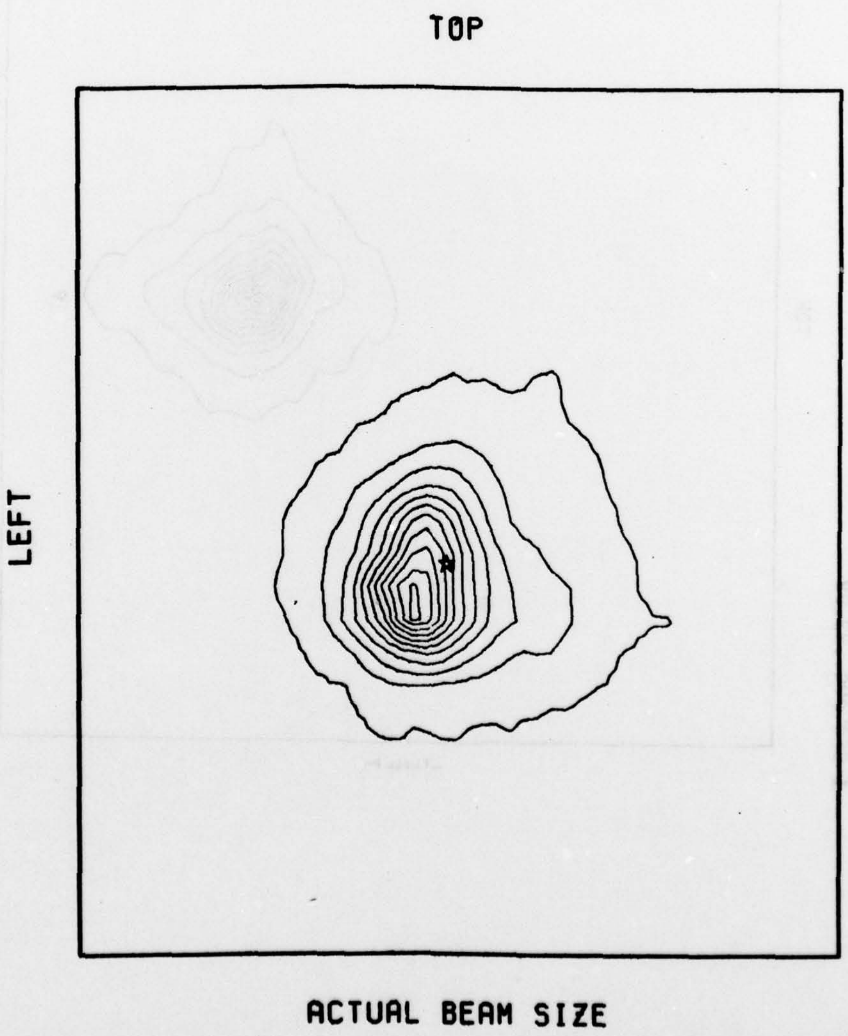

Figure 7. Typical IRDAPS Isoirradiance Contour Plot of EG&G Data. The star Near the Center Denotes Location of Beam Centroid.

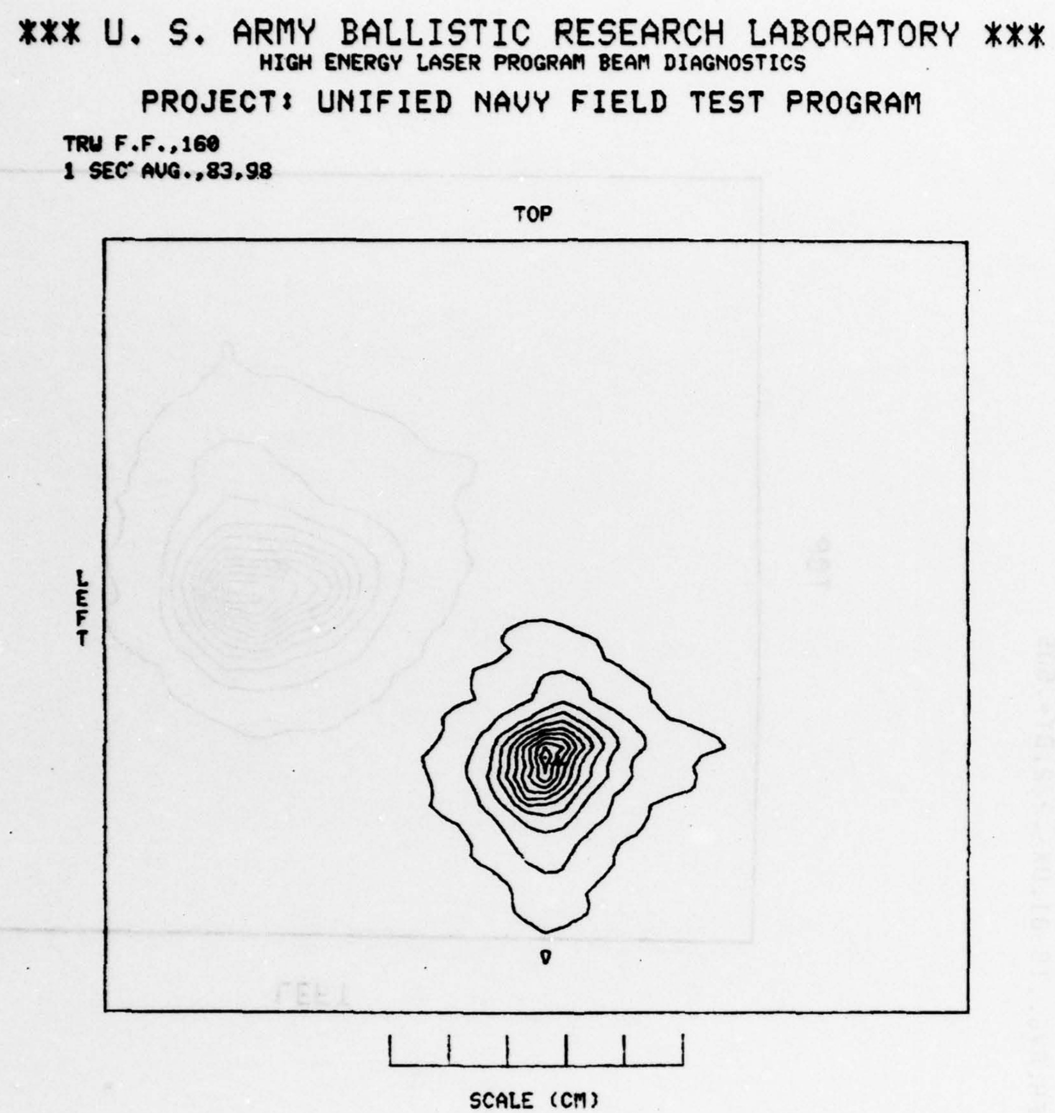

Figure 7a. Typical IRDAPS Isoirradiance Contour Plot of AGA Camera Data. The + Sign Near the Center is the Location of the Beam Centroid.

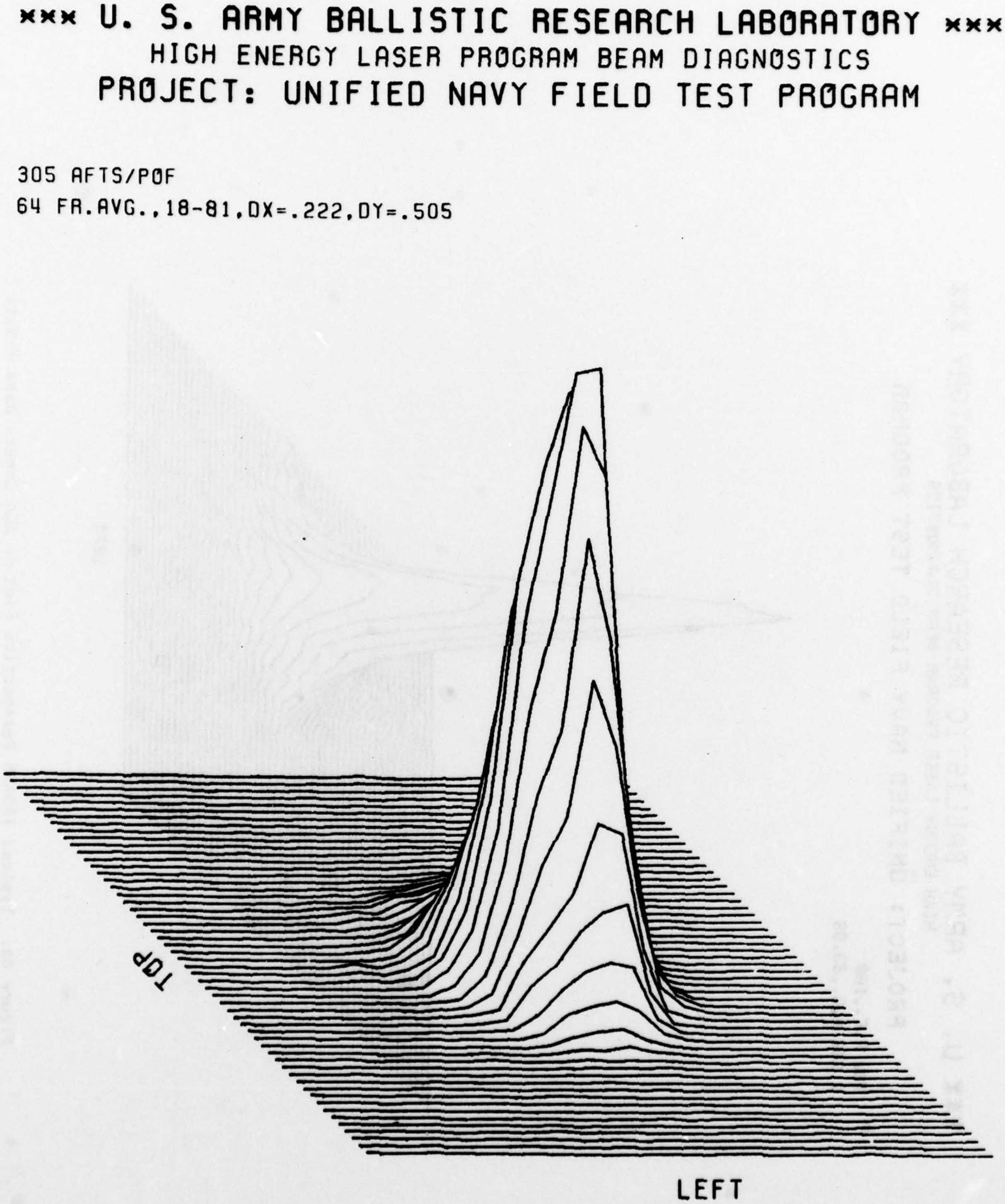

Figure 8. Typical IRDAPS Perspective Plot of EG&G Camera Data

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HIGH ENERGY LASER PROGRAM BEAM DIAGNOSTICS

PROJECT: UNIFIED NAVY FIELD TEST PROGRAM

TRU F.F.,160

1 SEC AUG.,83,98

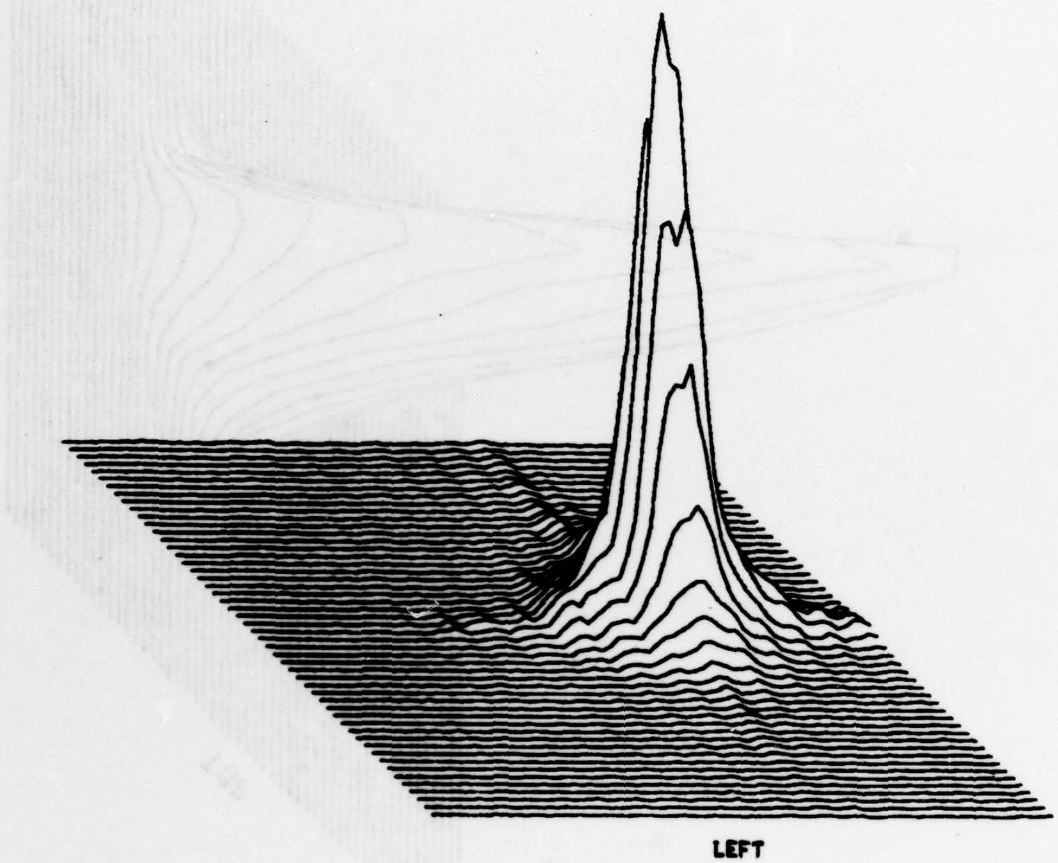

Figure 8a. Typical IRDAPS Perspective Plot of AGA Camera Data. Note Presence of Beam Aperture Diffraction Effects.

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